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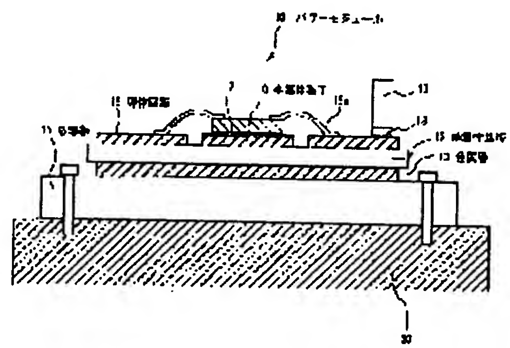
(54) RADIATING PLATE MADE OF SILICON CARBIDE AND METAL COMPOSITE MATERIAL AND BOARD FOR MODULE

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a radiating plate capable of being suitably used as a board for a module for mounting a semiconductor element having a large heating amount, excellent durability for a temperature cycle due to substantially equal thermal expansion coefficient to that of an aluminum nitride board having sufficiently highly thermal conductivity.

SOLUTION: The radiating plate comprises a silicon carbide and metal composite material impregnated with a metal in open pores existed in a porous texture constituted of a silicon carbide crystal. In this case, the mean grain size of the crystal is 20 μm or more, its porosity is 30% or less, its thermal conductivity is 100 W/m.K or more. The plate comprises 15 to 50 pts.wt. of metal to 100 pts.wt. of the silicon carbide.



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CLAIMS

[Claim(s)]
[Claim 1] The heat sink to which an open pore exists all over the porous structure constituted with a silicon carbide crystal, a metal is the heat sink which consists of silicon carbide and metal complex with which it sank in, and the mean particle diameter of said silicon carbide crystal consists of silicon carbide and metal complex characterized by for 30% or less and thermal conductivity being [for 20 micrometers or more and porosity] 100 or more W/m-K, and the metal of 15 - 50 weight section sinking in to the silicon carbide 100 weight section into the open pore.
[Claim 2] The heat sink which mean particle diameter becomes from silicon carbide and metal complex 50-90 volume % Including the coarse silicon carbide crystal which is 25-150 micrometers according to claim 1, 10-50 volume % Including the fine silicon carbide crystal whose mean particle diameter is 0.1-1.0 micrometers.
[Claim 3] one principal plane -- a conductor -- the substrate for modules which is a substrate for modules equipped with the insulating substrate with which the circuit was formed, and the heat sink joined to other principal planes of said insulating substrate through the metal layer for carrying a semiconductor device, and is characterized by using the heat sink according to claim 1 for said heat sink.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the substrate for modules for carrying a semiconductor device with big calorific value with which the heat sink excellent in the heat dissipation property and this heat sink were used.
[0002]

[Description of the Prior Art] The substrate for modules which is excellent in the heat dissipation property equipped with the insulating substrate and the heat sink as a substrate which mounts the power semiconductor device accompanied by a lot of generation of heat at the time of actuation like IGBT (insulated-gate mold bipolar transistor) or SIT (static induction transistor) is used.
[0003] Drawing 5 is the sectional view having shown typically the power module with which this kind of substrate for modules was used. this power module 20 -- one principal plane of the insulating substrate 12 -- a conductor -- a circuit 15 forms -- having -- this conductor -- a semiconductor device 16 carries in a part of circuit 15 -- having -- **** -- other conductors -- the circuit 15 and the semiconductor device 16 are connected by wire bonding which used wire 15a. moreover, a conductor -- the external terminal 19 is connected to the end of a circuit 15 through the solder layer 18.
[0004] On the other hand, the metal layer 13 is mostly formed in the whole surface, and the heat sink 21 is joined to this metal layer 13 by the base of the insulating substrate 12 through the solder layer 14.
[0005] By this power module 20, although a lot of heat occurs in a semiconductor device 16 by actuation of switching etc., since stripping of this heat is carried out outside through the insulating substrate 12, the metal layer 14, and a heat sink 11, it can prevent an extremes-of-temperature rise of a semiconductor device 16.
[0006] the former -- this conductor -- as an ingredient which constitutes a circuit 15 and the metal layer 13, copper is used and, on the other hand, ceramics, such as an alumina, were used as an ingredient which constitutes the insulating substrate 12.
[0007] However, by the power module 20 using such an ingredient, when processes, such as soldering of a semiconductor device 16, generation of heat of the semiconductor device 16 at the time of use, etc. received a temperature cycle, the problem that a crack will occur was in the insulating substrate 12 with the thermal stress resulting from the differential thermal expansion of copper and a ceramic.
[0008] in order to solve such a problem -- a conductor -- the power module with which the alumimium nitride substrate which uses the small aluminum of deformation resistance as a metal for circuits, and is excellent in the heat conductivity as an insulating substrate 12 was used is developed. Moreover, by this power module, the so-called AlSiC which infiltrated aluminum into the silicon carbide porous body is used as a heat sink 11.
[0009] the power module for which these ingredients were used -- a conductor -- the crack of the insulating substrate 12 resulting from the differential thermal expansion of a circuit 15 and the insulating substrate 12 etc. can be prevented. Moreover, since it is comparatively close to alumimium nitride, as for the heat sink 11 which consists of AlSiC, the coefficient of thermal expansion is hard to form a crack etc. in a part for the joint of the insulating substrate 12 and a heat sink 11. Furthermore, since the thermal conductivity of a heat sink 11 is also high, the substrate which consists of this heat sink, an insulating substrate, etc. excels [heat sink] in the heat dissipation property.
[0010] However, it was hard to say that the coefficient of thermal expansion of coefficient of thermal expansion of the insulating substrate 12 which consists of alumimium nitride of both corresponds with 4.5x10-6 (/degree C) extent to the coefficient of thermal expansion of a heat sink 11 which consists of this conventional AlSiC being 6.7x10-6 (/degree C) extent since the coefficient of thermal expansion of a heat sink 11 is about 1.5 times larger, and the thermal conductivity of a heat sink 11 was not able to be referred to as enough, either.
[0011]
[Problem(s) to be Solved by the Invention] This invention is made in view of the above-mentioned technical problem, and since thermal conductivity is high enough and coefficient of thermal expansion with an alumimium nitride substrate also has it, it aims at offering the heat sink which can be used suitable for the substrate for carrying a semiconductor device with such large calorific value, and the substrate for modules with which this heat sink was used. [almost equal]
[0012]
[Means for Solving the Problem] An open pore exists all over the porous structure constituted with a silicon carbide crystal, into the open pore, a metal is the heat sink which consists of silicon carbide and metal complex with which it sank in, for the mean particle diameter of the above-mentioned

silicon carbide crystal, 20 micrometers or more and porosity are [30% or less and thermal conductivity] 100 or more W/m-K, and the heat sink which consists of silicon carbide and metal complex of this invention is characterized by for the metal of 15 - 50 weight section to sink in to the silicon carbide 100 weight section.

[0013] moreover, the substrate for modules of this invention -- one principal plane -- a conductor -- it is the substrate for modules equipped with the insulating substrate with which the circuit was formed, and the heat sink joined to other principal planes of the above-mentioned insulating substrate through the metal layer for carrying a semiconductor device, and is characterized by using the heat sink which consists of the above-mentioned silicon carbide and metal complex as a heat sink. Hereafter, this invention is explained to a detail.

[0014]

[Embodiment of the Invention] First, the heat sink (only henceforth a heat sink) which consists of silicon carbide and metal complex of this invention is explained. An open pore exists all over the porous structure constituted with a silicon carbide crystal, into the open pore, a metal is the complex with which it sank in, for the mean particle diameter of the above-mentioned silicon carbide crystal, 20 micrometers or more and porosity are [30% or less and thermal conductivity] 100 or more W/m-K, and the silicon carbide and metal complex (only henceforth complex) which constitutes the heat sink of this invention are characterized by the metal of 15 - 50 weight section sinking in to the silicon carbide 100 weight section.

[0015] In the above-mentioned complex, since the mean particle diameter of a silicon carbide crystal is set as the comparatively big value of 20 micrometers or more, thermal conductivity is higher compared with the former. The effectiveness in which, as for this, heat conducts the interior of a crystal is because thermal conductivity becomes high so that mean particle diameter is large, since it is generally high compared with the effectiveness in which heat conducts between crystals. Moreover, in the complex of this invention, sintering advances, and since neck association is large as shown in the scanning electron microscope photograph (SEM photograph) of drawing 2 , thermal conductivity is high further. However, since neck association does not advance, either, when sintering does not advance as shown in the SEM photograph of drawing 3 , thermal conductivity does not become high.

[0016] Moreover, it has also contributed to thermally conductive improvement that the porosity of porous structure is set as the small value of 30% or less. That is, if porosity becomes small, as a result of the openings in porous structure decreasing in number, it is because it becomes easy to conduct heat. Furthermore, that the metal of 15 - 50 weight section sinks in to the silicon carbide 100 weight section has also contributed to improvement in thermal conductivity.

[0017] The value of the heat conductivity turns into 100 or more W/m-K and a big value, and the above-mentioned complex stops also being able to produce the variation in temperature easily, as a result of being constituted in this way. As for the value of thermal conductivity, it is desirable that it is 180 - 280 W/m-K, and it is more desirable that it is 200 - 260 W/m-K. In the above-mentioned complex, the above-mentioned desirable thermal conductivity can be attained by setting the porosity of the above-mentioned open pore, the particle size of a particle, etc. as the still more desirable range.

[0018] The mean particle diameter of the silicon carbide which constitutes the above-mentioned complex has desirable 20-100 micrometers, its 30-90 micrometers are more desirable, and its 40-70 micrometers are the most desirable. When mean particle diameter becomes large too much, there is a possibility that eburnation of the complex may be carried out too much. Moreover, 5 - 30% of the porosity of the open pore of the above-mentioned silicon carbide is desirable, is more desirable, and is the most desirable. [10 - 20% of] [10 - 20% of]

[0019] Moreover, as for the above-mentioned complex, it is desirable 50-90 volume % That it is what is included about the coarse silicon carbide crystal (henceforth a rough crystal) whose mean particle diameter is 25-150 micrometers, 10-50 volume % Including the fine silicon carbide crystal (henceforth a thin crystal) whose mean particle diameter is 0.1-1.0 micrometers.

[0020] As mentioned above, in the case of the complex with which a thin crystal and a rough crystal are included by the proper ratio, as the SEM photograph of drawing 4 showed, the opening formed between rough crystals will tend to be in the condition of having filled up with the thin crystal, and

the ratio of a substantial opening becomes small. Consequently, the thermal resistance of complex becomes still smaller and it is thought that this is contributing to improvement in thermal conductivity greatly. On the other hand, since the ratio of an opening will become large even if neck association advances to some extent if a thin crystal does not exist in the surroundings of a rough crystal as the SEM photograph of drawing 5 showed, thermal conductivity seldom improves.

[0021] The mean particle diameter of a thin crystal has desirable 0.1-1.0 micrometers, its 0.2-0.9 micrometers are more desirable, and its 0.3-0.7 micrometers are the most desirable.

[0022] since use of expensive impalpable powder is needed when it is going to make mean particle diameter of a thin crystal very small -- high-boiling [of ingredient cost] -- being ****** -- there is ********. On the contrary, when the mean particle diameter of a thin crystal becomes large too much, there is a possibility that it may become impossible to be filled up with the opening formed between rough crystals, and it may become impossible to fully reduce the thermal resistance of complex.

[0023] In this complex, as for a thin crystal, 10-50 volume % Being contained is desirable, 15-40 volume % Being contained is more desirable, and 20-40 volume % Being contained is most desirable. When the content ratio of a thin crystal becomes small too much, the thin crystal of sufficient amount to be filled up with the opening formed between rough crystals becomes is hard to be secured, and there is a possibility that it may become impossible to reduce the thermal resistance of complex certainly. On the contrary, if the content ratio of a thin crystal becomes large too much, the thin crystal filled up with the above-mentioned opening will become an excess rather, and, originally the rough crystal of extent required for thermally conductive improvement will no longer be secured. Therefore, there is a possibility that the thermal resistance of complex may become large on the contrary.

[0024] In the above-mentioned complex, the mean particle diameter of a rough crystal has desirable 25-150 micrometers, its 40-100 micrometers are more desirable, and its 60-80 micrometers are the most desirable. If it is going to make mean particle diameter of a rough crystal small, as a result of a particle-size difference with the above-mentioned thin crystal grain child becoming small, there is a possibility that it may become impossible to expect the thermal resistance reduction effectiveness by mixing with a thin crystal and a rough crystal. On the contrary, if the mean particle diameter of a rough crystal becomes large too much, even if there is a thin crystal of sufficient amount from each opening formed between rough crystals becoming large, it will become difficult to fully be filled up with the opening concerned. Therefore, there is a possibility that it may become impossible to fully reduce the thermal resistance of complex.

[0025] In the above-mentioned complex, 50-90 volume % Being contained is desirable, as for a rough crystal, 60-85 volume % Being contained is more desirable, and 60-80 volume % Being contained is most desirable. When the content ratio of a rough crystal becomes small too much, there is a possibility that the rough crystal of extent required for improvement in thermal conductivity may originally no longer be secured, and the thermal resistance of complex may become large on the contrary. When the content ratio of a rough crystal becomes large too much, the content ratio of a thin crystal becomes small relatively, and it becomes impossible on the contrary, to fully be filled up with the opening formed between rough crystals. Therefore, there is a possibility that it may become impossible to reduce the thermal resistance of complex certainly.

[0026] In the complex which constitutes the heat sink of this invention, the metal of 15 - 50 weight section sinks in to the silicon carbide 100 weight section. By performing metal sinking in, it fills up with a metal in the open pore of a sintered compact, it serves as a precise object seemingly, and improvement in thermal conductivity and reinforcement is achieved as a result.

[0027] Especially as the above-mentioned metal for sinking in, metal silicon is desirable. In addition to familiarity by silicon carbide being the good matter, metal silicon has thermal conductivity with high itself. Therefore, improvement in thermal conductivity and reinforcement can be certainly attained by being filled up with metal silicon in the open pore of a sintered compact.

[0028] In this case, as for metal silicon, it is desirable that 15-45 weight section sinking in is carried out to the silicon carbide 100 weight section, and it is more desirable that 15-39 weight section sinking in is carried out. There is a possibility that it may become impossible to fully fill up with an open pore that the amount of sinking in is under 15 weight sections, and it may become impossible to

reduce the thermal resistance of complex certainly. If the amount of sinking in exceeds 30 weight sections, as a result of the ratio of a crystal part falling relatively, depending on the case, thermal conductivity may fall on the contrary.
[0029] In addition, when chosen, the things, for example, the metal aluminum, other than metal silicon, the amount of sinking in has desirable 20 – 50 weight section to the silicon carbide 100 weight section. When the amount of sinking in deviates from the above-mentioned range, there is a possibility of causing the decline in thermal conductivity and increase of coefficient of thermal expansion.
[0030] Next, how to manufacture the heat sink which consists of such complex is explained. The above-mentioned heat sink is manufactured through the ingredient preparation process which mixes impalpable powder at a predetermined rate in the end of coarse powder, a forming cycle, a baking process, and a metal sinking-in process. A metal sinking-in process may be performed before a baking process, and may be performed after a baking process.
[0031] In the above-mentioned ingredient preparation process, to the coarse powder end of alpha mold silicon carbide with a mean particle diameter of 5-100 micrometers, 10-100 weight section combination of the impalpable powder of alpha mold silicon carbide with a mean particle diameter of 0.1-1.0 micrometers is carried out, and this is mixed to homogeneity.
[0032] The mean particle diameter in the coarse powder end of alpha mold silicon carbide used as a raw material has desirable 5-100 micrometers, its 15-75 micrometers are more desirable, and its 25-60 micrometers are more desirable. Moreover, the mean particle diameter of the impalpable powder of alpha mold silicon carbide has desirable 0.1-1.0 micrometers, its 0.1-0.8 micrometers are more desirable, and its 0.2-0.5 micrometers are the most desirable.
[0033] The loadings of the impalpable powder to the 100 weight sections have the desirable 10 – 100 weight section, its 15 – 65 weight section is more desirable, and its 20 – 60 weight section is the most desirable in the end of coarse powder.
[0034] In this ingredient preparation process, a raw material slurry is prepared by blending distributed solvents other than the above-mentioned silicon carbide powder, such as binders for shaping, such as polyvinyl alcohol and acrylic resin, alcohol, water, and benzene, if needed, and kneading this using a kneader etc., after mixing by a vibration mill etc.
[0035] Moreover, it is desirable that the organic substance which serves as a carbon source further is blended one to 10% of the weight by carbon weight conversion into the above-mentioned raw material slurry, and it is more desirable to be blended six to 9% of the weight. That is, when the carbon originating in the above-mentioned organic substance adheres to the front face of the silicon carbide of a sintered compact, the metal silicon and carbon which have invaded react and silicon carbide newly generates there. Therefore, it is because necking strong there occurs and improvement in thermal conductivity and reinforcement is achieved by this (refer to drawing 4).
[0036] As the above-mentioned organic substance, phenol resin, carbon black, acetylene black, a pitch, tar, etc. are mentioned, for example. When a ball mill is used for phenol resin also in this, it is advantageous at the point that a raw material is mixable to homogeneity.
[0037] In a forming cycle, after forming the granulation of silicon carbide using this raw material slurry, it fabricates in a predetermined configuration using metal mold etc. As an approach of granulating silicon carbide powder, an approach better known than before can be used like the granulating method (the spray-drying method) by spray drying, for example. Moreover, compacting pressure is 1.0 – 1.5 t/cm2. It is desirable and is 1.1 – 1.4 t/cm2. It is more desirable. Moreover, the consistency of the Plastic solid acquired is 2.0 g/cm3. The above is desirable and it is 3 2.2-2.7g/cm. It is more desirable.
[0038] In a baking process, the acquired Plastic solid is calcinated in a 1700-2400-degree C temperature requirement, and a porous body is produced. 2000-2400 degrees C of burning temperature are desirable, and its 200-2300 degrees C are more desirable. Under the present circumstances, the interior of a firing furnace is maintained at a non-oxidizing atmosphere or inert atmospheres, such as an argon, helium, and nitrogen. In addition, the inside of a firing furnace may be made into a vacua at this time.
[0039] Furthermore, in order to promote growth of the neck section at the time of baking, it is desirable to control volatilization of the silicon carbide from a Plastic solid. There is the approach of

inserting in a Plastic solid as an approach of controlling volatilization of the silicon carbide from a Plastic solid in the heat-resistant container which can intercept invasion of the open air. As a formation ingredient of the above-mentioned heat-resistant container, a graphite or silicon carbide is suitable.

[0040] In the continuing metal sinking-in process, as it is the following, a metal is sunk into a porous body. For example, when sinking in metal silicon, it is desirable to sink a carbonaceous material into a sintered compact beforehand. As such a carbonaceous material, various organic substances, such as furfural resin, phenol resin, a ligninsulfonic acid salt, polyvinyl alcohol, corn starch, ****, a coal-tar pitch, and alginate, are mentioned, for example. In addition, pyrolysis matter like carbon black and acetylene black can be used similarly.

[0041] Since the film of new silicon carbide is formed in the front face of the open pore of a sintered compact by infiltrating the above-mentioned carbonaceous material beforehand, association with melting silicon and a porous body will become firm by this. Moreover, the reinforcement of a sintered compact also becomes strong according to sinking [of a carbonaceous material] in.

[0042] The approach of making carry out heating melting of the metal silicon, and sinking in as an approach filled up with metal silicon into an open pore, for example is mentioned. Moreover, the metal silicon which carried out pulverization is distributed in a dispersion medium, it can be made to be able to back-dry and the approach of heating more than the melting temperature of metal silicon which infiltrated these dispersion liquid into the porous body can also be applied. Sinking [of the above-mentioned metal] in may be carried out to the Plastic solid before calcinating. Then, while performing cutting to a sintered compact as occasion demands, polish etc. is given, and a heat sink is produced by considering as the plate of a predetermined configuration.

[0043] Thus, since the heat sink which consists of silicon carbide and metal complex of a new configuration of having been obtained contains the metal while the value of thermal conductivity is excellent in 100 or more W/m-K and thermal conductivity, it is excellent also in a mechanical strength. Furthermore, it can consider as the heat sink which was further excellent in thermal conductivity depending on manufacture conditions with thermal conductivity 180 - 280 W/m-K, and 200 - 260 W/m-K. Such a heat sink is the optimal as a heat sink used for the substrate for modules which carries out the following.

[0044] Next, the substrate for modules with which the above-mentioned heat sink was used is explained. the substrate for modules of this invention -- one principal plane -- a conductor -- it is the substrate for modules equipped with the insulating substrate with which the circuit was formed, and the heat sink joined to other principal planes of the above-mentioned insulating substrate through the metal layer for carrying a semiconductor device, and is characterized by using the heat sink which turns into the above-mentioned heat sink from the above-mentioned silicon carbide and metal complex.

[0045] Drawing 1 is the sectional view showing typically the power module with which the substrate for modules of this invention was used.

[0046] this power module 10 -- the top face of the insulating substrate 12 -- a conductor -- a circuit 15 forms -- having -- this conductor -- a semiconductor device 16 minds [a part of] the solder layer 17, and connects and fixes to it -- having -- **** -- a conductor -- other parts and semiconductor devices 16 of a circuit 15 are connected by wire bonding which used wire 15a. moreover, a conductor -- the external terminal 19 is connected to the end of a circuit 15 through the solder layer 18.

[0047] On the other hand, the metal layer 13 is mostly formed in the whole surface, the heat sink 11 which consists of complex of this invention is directly joined to the metal layer 13 which consists of this aluminum etc. by the base of the insulating substrate 12, and this heat sink 11 is attached in it at the cooling unit 20. This heat sink 11 may be joined to the metal layer 14 through the low material with near aluminum etc. and coefficient of thermal expansion by which aluminum-Si was added.

[0048] The cooling unit 20 may be air cooling and may be a water cooling type. In the case of the water cooling type, refrigerants, such as water, are usually poured by the part which touches a heat sink 11.

[0049] this power module 10 -- a conductor -- the insulating substrate 12 and heat sink 11 which have a circuit 15 and the metal layer 13 constitute the substrate for modules of this invention.

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[0043] Thus, since the heat sink which consists of silicon carbide and metal complex of a new configuration of having been obtained contains the metal while the value of thermal conductivity is excellent in 100 or more W/m-K and thermal conductivity, it is excellent also in a mechanical strength. Furthermore, it can consider as the heat sink which was further excellent in thermal conductivity depending on manufacture conditions with thermal conductivity 180 - 280 W/m-K, and 200 - 260 W/m-K. Such a heat sink is the optimal as a heat sink used for the substrate for modules which carries out the following.

[0044] Next, the substrate for modules with which the above-mentioned heat sink was used is explained. the substrate for modules of this invention -- one principal plane -- a conductor -- it is the substrate for modules equipped with the insulating substrate with which the circuit was formed, and the heat sink joined to other principal planes of the above-mentioned insulating substrate through the metal layer for carrying a semiconductor device, and is characterized by using the heat sink which turns into the above-mentioned heat sink from the above-mentioned silicon carbide and metal complex.

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[0049] this power module 10 -- a conductor -- the insulating substrate 12 and heat sink 11 which have a circuit 15 and the metal layer 13 constitute the substrate for modules of this invention.

Although the heat sink which consists of silicon carbide and metal complex mentioned above as a heat sink 11 is used, this heat sink is excellent also in the mechanical property while showing for example, 200-260W/m and K, and very high thermal conductivity by choosing manufacture conditions. Moreover, since this heat sink 11 has a coefficient of thermal expansion almost equal to 3.5x10-6 to 5.0x10-6 (/degree C), and insulating substrates, such as alumimium nitride (coefficient of thermal expansion: about 4.5x10- 6/degree C), in room temperature -800 degree C, the endurance which was excellent also to the temperature cycle is shown. In addition, the thickness of this heat sink 11 usually has 3-4 desirablemm.

[0050] Although especially the quality of the material of the insulating substrate 12 is not limited, for example, an alumina, silicon nitride, alumimium nitride, etc. are mentioned, in these, alumimium nitride excellent in thermal conductivity is desirable. When the insulating substrate 12 consists of alumimium nitride, the alumimium nitride sintered compact may contain metallic oxides, such as an alkali-metal oxide, an alkaline-earth-metal oxide, and a rare earth oxide, 0.1 to 10% of the weight. as these oxides -- Y2 O3, CaO, Li2 O, and Rb 2O3 etc. -- it is mentioned.

[0051] a conductor -- as the quality of the material of a circuit 15 and the metal layer 13, although copper, aluminum, etc. are mentioned for example, while having comparatively high conductivity, the small aluminum of deformation resistance is desirable. When aluminum is especially used for the metal layer 13, it becomes possible to join to a heat sink 11 directly. If aluminum and silicon are used as a metal especially infiltrated into a heat sink 11, melting and since it is mixed, as for both, this aluminum, the aluminum in a heat sink, and silicon will be mutually joined firmly by the junction interface. in addition, an insulating substrate and a conductor -- junction of a circuit etc. can be performed using the low material containing aluminum-Si.

[0052] Although especially the semiconductor device carried in the substrate for modules of this invention is not limited, since this substrate for modules is excellent in the heat dissipation property, it is the optimal as an object for loading of a semiconductor device with much calorific value at the time of actuation. As such a semiconductor device, IGBT, SIT, etc. are mentioned, for example. Thus, the substrate for modules of this invention has the endurance which was excellent also to thermal shocks, such as a temperature cycle, while it is excellent in a heat dissipation property.

[0053]

[Example] Although an example is hung up over below and this invention is explained to it in more detail, this invention is not limited only to these examples.

[0054] an example 1 -- the impalpable powder (GMF-15H2) of alpha mold silicon carbide with a coarse powder end [of alpha mold silicon carbide with a mean particle diameter of 30 micrometers] (#400) and a mean particle diameter of 0.3 micrometers was first prepared as a start ingredient. And to the 100 weight sections, the above-mentioned impalpable powder 30 weight section was blended, and this was mixed to homogeneity in the above-mentioned end of coarse powder.

[0055] Next, after blending the polyvinyl alcohol 5 weight section, the phenol resin 3 weight section, and the water 50 weight section to this mixture 100 weight section, uniform mixture was obtained by mixing in a ball mill for 5 hours.

[0056] After carrying out predetermined time desiccation of this mixture and removing moisture to some extent, optimum dose extraction was carried out and that desiccation mixture was granulated. At this time, the moisture content of granulation was adjusted so that it might become about 0.8% of the weight. Subsequently, a metal force piston is used for the granulation of this mixture, and it is 2 1.3t/cm. It fabricated by the press pressure. the consistency of the acquired tabular generation form -- 2.6 g/cm3 it was .

[0057] Subsequently, the above-mentioned Plastic solid was put into the crucible made from a graphite, and the baking was performed using the tongue man mold firing furnace. Baking was carried out in the argon atmosphere of one atmospheric pressure. Moreover, it heated to 2200 degrees C which is a maximum temperature in 10-degree-C programming rate for /at the time of baking, and held at the temperature after that for 4 hours.

[0058] Subsequently, desiccation was performed after carrying out vacuum impregnation of the phenol resin (coking value: 30 % of the weight) to the obtained porosity sintered compact beforehand. Then, the front face of the above-mentioned porosity sintered compact was coated with the slurry containing metal silicon. Here, that with which 20 micrometers was mixed for mean particle diameter,

and 99% of the weight or more of the metal silicon powder 100 weight section and the 5% acrylic ester benzene solution 60 weight section were mixed for purity was used as the above-mentioned slurry. And the porosity sintered compact which coated metal silicon was heated with the programming rate of 450 degrees C/hour in the argon gas air current, and it held at 1450 degrees C of maximum temperatures for about 1 hour. By such processing, metal silicon was made to permeate into a porosity sintered compact, and silicon carbide and metal complex were obtained. In addition, the content of the metal silicon to the silicon carbide 100 weight section was set as 30 weight sections here.
[0059] the porosity of an open pore [in / in the base material which consists of obtained silicon carbide and metal complex / porous structure] -- 20% -- as a whole -- thermal conductivity -- the consistency as 210W/mandK, and the whole -- 3.0 g/cm3 it was . Moreover, the mean particle diameter of a silicon carbide crystal was 30 micrometers. 80 volume % Specifically, the rough crystal whose mean particle diameter is 40 micrometers was included, 20 volume % Including the thin crystal whose mean particle diameter is 1.0 micrometers.
[0060] Then, after performing figuring processing to the above-mentioned base material by well-known technique conventionally, polish processing etc. was performed and production of vertical:70mm, horizontal:130mm, and a thickness:3mm heat sink was completed.
[0061] next, a conductor -- the conductor which becomes the whole surface from aluminum with a thickness of 0.4mm as an insulating substrate which has a circuit etc. -- a circuit The substrate made from alumimium nitride with a thickness of 4mm to which it was joined using the low material containing aluminum-Si, and the aluminum plate used the same low material for, and was joined by other whole surface is used. The heat sink and the above-mentioned substrate made from alumimium nitride which were obtained were joined by inserting and sticking [heat and] an aluminum plate by pressure, and production of the substrate for modules was completed.
[0062] this the substrate for modules after presenting the thermo-cycle trial repeated 1000 times with the thermo cycle which keeps it at 150 degrees C after keeping the obtained substrate for modules at -55 degrees C -- length -- cutting -- the junction condition of a heat sink and an insulating substrate, and a conductor -- although the junction condition of a circuit, a metal layer, and an insulating substrate was observed under the microscope, the crack etc. was not observed at all.
[0063] Next, although the power module was actually operated and the temperature of an IGBT component was measured after carrying the IGBT component in this substrate for modules and attaching in a cooling unit, the IGBT component held the temperature which may fully function as a component.
[0064] While using the coarse powder end of alpha mold silicon carbide with example 2 mean particle diameter of 35 micrometers (#360), to the 100 weight sections, the above-mentioned impalpable powder 40 weight section was blended, and this was mixed to homogeneity in the above-mentioned end of coarse powder. About the other conditions, it was presupposed fundamentally that it is the same as that of an example 1.
[0065] consequently, the porosity of an open pore [in / in the base material which consists of obtained silicon carbide and metal complex / porous structure] -- the thermal conductivity as 17% and the whole -- the consistency as 220 W/m-K and the whole -- 3.0g/cm3 it was . Moreover, the mean particle diameter of a silicon carbide crystal was 36 micrometers. 80 volume % Specifically, the rough crystal whose mean particle diameter is 45 micrometers was included, 20 volume % Including the thin crystal whose mean particle diameter is 1.0 micrometers.
[0066] the junction condition of the heat sink after producing the substrate for modules like an example 1 and performing a thermo-cycle trial using this silicon carbide and metal complex, and an insulating substrate, and a conductor -- although the junction condition of a circuit was observed, the crack etc. was not observed at all.
[0067] Moreover, although the IGBT component was carried in this substrate for modules, this is attached in a cooling unit, and was operated and the temperature of an IGBT component was measured, the IGBT component held the temperature which may fully function as a component.
[0068] While using the coarse powder end of alpha mold silicon carbide with example 3 mean particle diameter of 57 micrometers (#240), to the 100 weight sections, the above-mentioned impalpable

powder 40 weight section was blended, and this was mixed to homogeneity in the above-mentioned end of coarse powder. About the other conditions, it was presupposed fundamentally that it is the same as that of an example 1.
[0069] consequently, the porosity of an open pore [in / in the base material which consists of obtained silicon carbide and metal complex / porous structure] -- the thermal conductivity as 15% and the whole -- the consistency as 230 W/m-K and the whole -- 3.1g/cm3 it was . Moreover, the mean particle diameter of a silicon carbide crystal was 65 micrometers. 80 volume % Specifically, the rough crystal whose mean particle diameter is 80 micrometers was included, 20 volume % Including the thin crystal whose mean particle diameter is 1.0 micrometers.
[0070] the junction condition of the heat sink after producing the substrate for modules like an example 1 and performing a thermo-cycle trial using this silicon carbide and metal complex, and an insulating substrate, and a conductor -- although the junction condition of a circuit was observed, the crack etc. was not observed at all.
[0071] Moreover, although the IGBT component was carried in this substrate for modules, this is attached in a cooling unit, and was operated and the temperature of an IGBT component was measured, the IGBT component held the temperature which may fully function as a component.
[0072] While using the coarse powder end of alpha mold silicon carbide with example of comparison 1 mean particle diameter of 10 micrometers, to the 100 weight sections, mean particle diameter blended the impalpable powder 45 weight section of alpha mold silicon carbide which is 0.7 micrometers, and mixed this to homogeneity in the above-mentioned end of coarse powder.
[0073] After blending the polyvinyl alcohol 5 weight section and the water 50 weight section to this mixture 100 weight section, uniform mixture was obtained by mixing in a ball mill for 5 hours.
[0074] After carrying out predetermined time desiccation of this mixture and removing moisture to some extent, optimum dose extraction was carried out and that desiccation mixture was granulated. Subsequently, a metal force piston is used for the granulation of this mixture, and it is 2 0.6t/cm. It fabricated by the press pressure. the consistency of the acquired tabular generation form -- 2.0 g/cm3 it was . Then, the condition metal silicon same to this Plastic solid as an example 1 was sunk in.
[0075] Subsequently, the above-mentioned Plastic solid was put into the crucible made from a graphite, and the baking was performed using the tongue man mold firing furnace. Baking was carried out in the argon atmosphere of one atmospheric pressure. Moreover, it heated to 1700 degrees C which is a maximum temperature in 10-degree-C programming rate for /at the time of baking, and held at the temperature after that for 4 hours.
[0076] the porosity of an open pore [in / in the base material which consists of obtained silicon carbide and metal complex / porous structure] -- 38% -- as a whole -- thermal conductivity -- the consistency as 80W/mandK, and the whole -- 2.8 g/cm3 it was . Moreover, the mean particle diameter of a silicon carbide crystal was 10 micrometers.
[0077] The substrate for modules was produced like the example 1 using this silicon carbide and metal complex. Moreover, although the IGBT component was carried in this substrate for modules, this is attached in a cooling unit, and was operated and the temperature of an IGBT component was measured, temperature rose with the passage of time and the IGBT component has exceeded the temperature which may fully function as a component.
[0078]
[Effect of the Invention] Since it is constituted as mentioned above, since thermal conductivity is high enough and coefficient of thermal expansion with an alumimium nitride substrate also has it, the heat sink which consists of silicon carbide and metal complex of this invention is excellent in the endurance over a temperature cycle, and can be suitably used as a substrate for modules for carrying a semiconductor device with large calorific value. [almost equal] Moreover, since the substrate for modules of this invention is constituted as mentioned above, it is excellent in a heat dissipation property and endurance.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the sectional view showing the substrate for modules of this invention typically.
[Drawing 2] It is the SEM photograph in which the organization of the silicon carbide and metal complex which constitutes the heat sink of this invention is shown.
[Drawing 3] It is the SEM photograph in which the organization of the conventional silicon carbide and metal complex is shown.
[Drawing 4] It is the SEM photograph in which the organization of the silicon carbide and metal complex which constitutes the heat sink of this invention is shown.
[Drawing 5] It is the SEM photograph in which the organization of the conventional silicon carbide and metal complex is shown.
[Drawing 6] It is the sectional view showing the conventional power module typically.
[Description of Notations]
10 Power Module
11 Heat Sink
12 Insulating Substrate
13 Metal Plate
14, 17, 18 Solder layer
15 Conductor -- Circuit
15a Wire
16 Semiconductor Device
17 18 Solder layer
19 External Terminal

[Translation done.]

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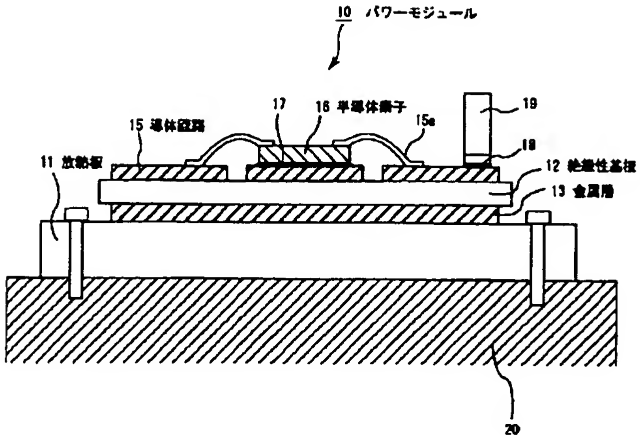
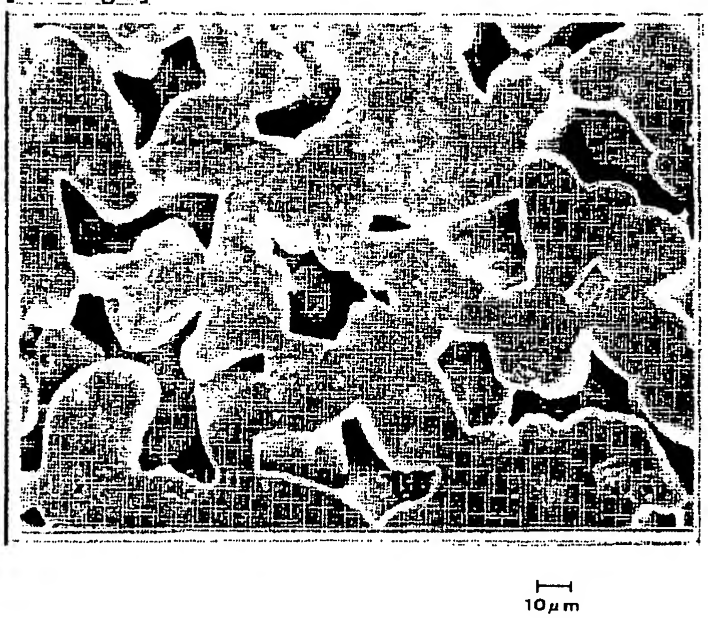
DRAWINGS

[Drawing 1]



[Drawing 2]



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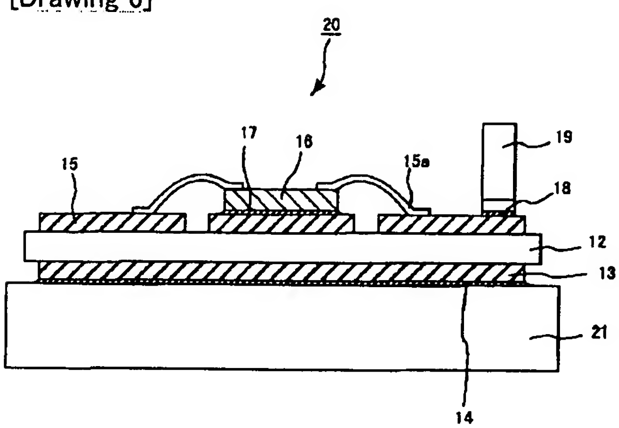

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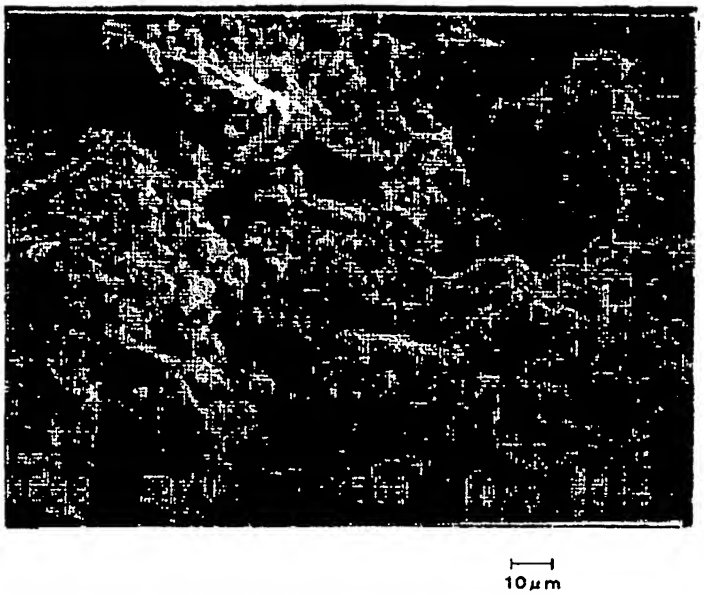
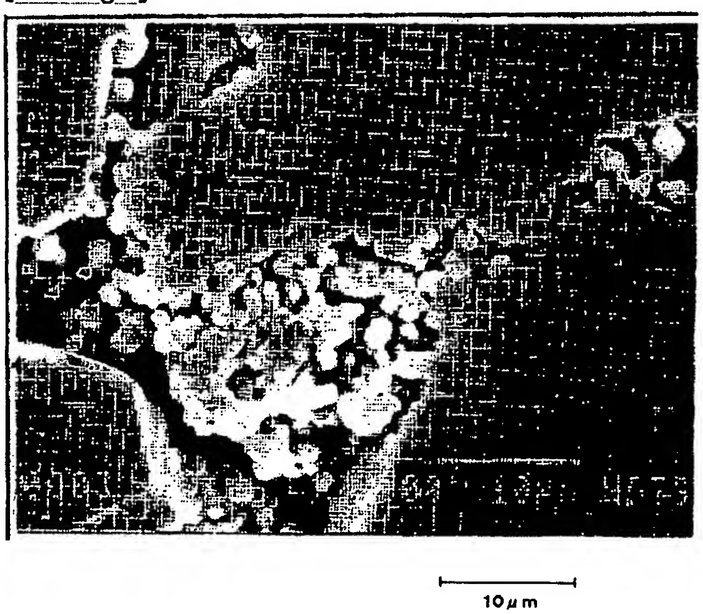
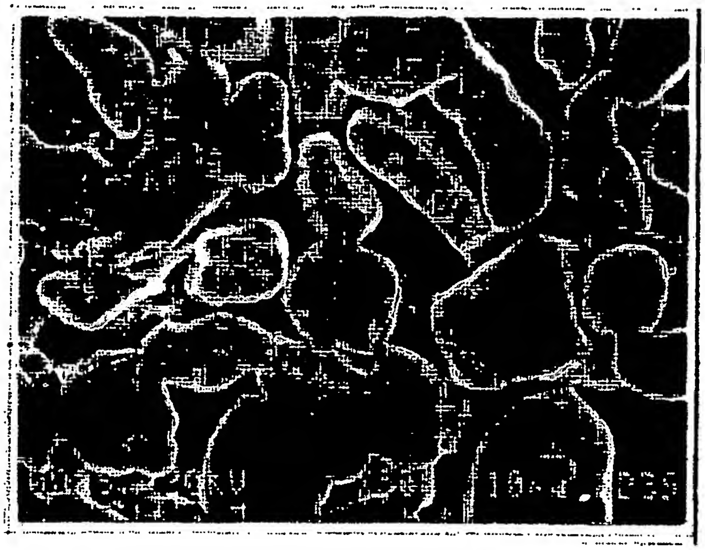


[Drawing 4]



[Drawing 5]



10μm

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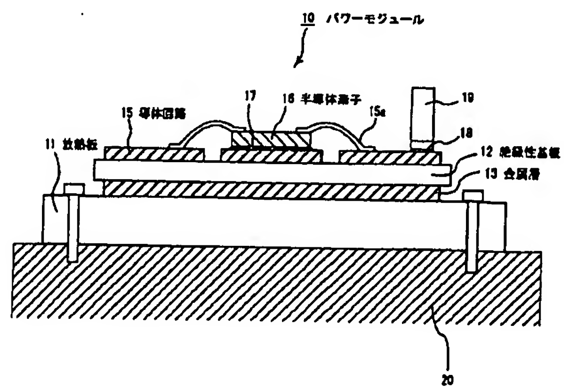
(54)【発明の名称】　炭化珪素・金属複合体からなる放熱板及びモジュール用基板

(57)【要約】

【課題】　熱伝導率が充分に高く、かつ、窒化アルミニウム基板との熱膨張率もほぼ等しいため温度サイクルに対する耐久性に優れ、発熱量の大きい半導体素子を搭載するためのモジュール用基板として好適に用いることができる放熱板を提供する。

【解決手段】　炭化珪素結晶によって構成される多孔質組織中に開放気孔が存在し、その開放気孔中に金属が含浸された炭化珪素・金属複合体からなる放熱板であって、前記炭化珪素結晶の平均粒径が２０μｍ以上、気孔率が３０％以下、熱伝導率が１００Ｗ／ｍ・Ｋ以上であり、炭化珪素１００重量部に対して１５～５０重量部の金属が含浸されていることを特徴とする炭化珪素・金属複合体からなる放熱板。



【特許請求の範囲】

【請求項１】　炭化珪素結晶によって構成される多孔質組織中に開放気孔が存在し、その開放気孔中に金属が含浸された炭化珪素・金属複合体からなる放熱板であって、前記炭化珪素結晶の平均粒径が２０μm以上、気孔率が３０%以下、熱伝導率が１００W／m・K以上であり、炭化珪素１００重量部に対して１５～５０重量部の金属が含浸されていることを特徴とする炭化珪素・金属複合体からなる放熱板。

【請求項２】　平均粒径が０．１～１．０μmの細かい炭化珪素結晶を１０～５０体積%含み、かつ、平均粒径が２５～１５０μmの粗い炭化珪素結晶を５０～９０体積%含む請求項１記載の炭化珪素・金属複合体からなる放熱板。

【請求項３】　一主面に導体回路が形成された絶縁性基板と、前記絶縁性基板の他の主面に金属層を介して接合された放熱板とを備えた、半導体素子を搭載するためのモジュール用基板であって、前記放熱板には、請求項１記載の放熱板が用いられていることを特徴とするモジュール用基板。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、放熱特性に優れた放熱板、及び、該放熱板が用いられた、発熱量の大きな半導体素子を搭載するためのモジュール用基板に関する。

【０００２】

【従来の技術】ＩＧＢＴ（絶縁ゲート型バイポーラトランジスタ）やＳＩＴ（静電誘導トランジスタ）のような動作時に多量の発熱を伴う電力用半導体素子を実装する基板として、絶縁性基板と放熱板とを備えた放熱特性に優れるモジュール用基板が用いられている。

【０００３】図５は、この種のモジュール用基板が用いられたパワーモジュールを模式的に示した断面図である。このパワーモジュール２０では、絶縁性基板１２の一主面に導体回路１５が形成され、この導体回路１５の一部に半導体素子１６が搭載されており、他の導体回路１５と半導体素子１６とは、ワイヤー１５ａを用いたワイヤーボンディングにより接続されている。また、導体回路１５の一端には、外部端子１９が半田層１８を介して接続されている。

【０００４】一方、絶縁性基板１２の底面には、ほぼ全面に金属層１３が形成され、この金属層１３には、半田層１４を介して放熱板２１が接合されている。

【０００５】このパワーモジュール２０では、スイッチング等の動作により半導体素子１６に多量の熱が発生するが、この熱は、絶縁性基板１２、金属層１４及び放熱板１１を介して外部に放散されるため、半導体素子１６の過度の温度上昇を防止することができる。

【０００６】従来より、この導体回路１５や金属層１３を構成する材料として、銅が用いられており、一方、絶縁性基板１２を構成する材料として、アルミナ等のセラミックが用いられていた。

【０００７】しかし、このような材料を用いたパワーモジュール２０では、半導体素子１６の半田付け等の工程や使用時の半導体素子１６の発熱等により温度サイクルを受けたとき、銅とセラミックとの熱膨張差に起因する熱応力により、絶縁性基板１２に割れが発生してしまうという問題があった。

【０００８】このような問題を解決するため、導体回路用の金属として、変形抵抗の小さいアルミニウムを使用し、かつ、絶縁性基板１２として、熱伝導率に優れる窒化アルミニウム基板が使用されたパワーモジュールが開発されている。また、このパワーモジュールでは、放熱板１１として、炭化珪素多孔質体中にアルミニウムを含浸させた、いわゆるＡｌＳｉＣが使用されている。

【０００９】これらの材料が使用されたパワーモジュールでは、導体回路１５と絶縁性基板１２との熱膨張差に起因する、絶縁性基板１２の割れ等を防止することができる。また、ＡｌＳｉＣからなる放熱板１１は、その熱膨張率が比較的窒化アルミニウムに近いため、絶縁性基板１２と放熱板１１との接合部分にクラック等が形成されにくい。さらに、放熱板１１は、熱伝導率も高いため、この放熱板と絶縁性基板等から構成される基板は、放熱特性に優れている。

【００１０】しかしながら、この従来のＡｌＳｉＣからなる放熱板１１の熱膨張係数は、６．７×１０$^{-6}$（／℃）程度であるのに対し、窒化アルミニウムからなる絶縁性基板１２の熱膨張率は、４．５×１０$^{-6}$（／℃）程度で、放熱板１１の熱膨張係数の方が約１．５倍大きいため、両者の熱膨張率が一致しているとは言いがたく、また、放熱板１１の熱伝導率も充分とは言えなかった。

【００１１】

【発明が解決しようとする課題】本発明は、上記課題に鑑みてなされたものであり、熱伝導率が充分に高く、かつ、窒化アルミニウム基板との熱膨張率もほぼ等しいため、このような発熱量の大きい半導体素子を搭載するための基板に好適に用いることができる放熱板、及び、該放熱板が用いられたモジュール用基板を提供することを目的とする。

【００１２】

【課題を解決するための手段】本発明の炭化珪素・金属複合体からなる放熱板は、炭化珪素結晶によって構成される多孔質組織中に開放気孔が存在し、その開放気孔中に金属が含浸された炭化珪素・金属複合体からなる放熱板であって、上記炭化珪素結晶の平均粒径が２０μm以上、気孔率が３０%以下、熱伝導率が１００W／m・K以上であり、炭化珪素１００重量部に対して１５～５０重量部の金属が含浸されていることを特徴とするものである。

【００１３】また、本発明のモジュール用基板は、一主面に導体回路が形成された絶縁性基板と、上記絶縁性基板の他の主面に金属層を介して接合された放熱板とを備えた、半導体素子を搭載するためのモジュール用基板であって、放熱板として、上記炭化珪素・金属複合体からなる放熱板が用いられていることを特徴とするものである。以下、本発明を詳細に説明する。

【００１４】

【発明の実施の形態】まず、本発明の炭化珪素・金属複合体からなる放熱板（以下、単に放熱板ともいう）について説明する。本発明の放熱板を構成する炭化珪素・金属複合体（以下、単に複合体ともいう）は、炭化珪素結晶によって構成される多孔質組織中に開放気孔が存在し、その開放気孔中に金属が含浸された複合体であって、上記炭化珪素結晶の平均粒径が２０μｍ以上、気孔率が３０％以下、熱伝導率が１００Ｗ／ｍ・Ｋ以上であり、炭化珪素１００重量部に対して１５～５０重量部の金属が含浸されていることを特徴とする。

【００１５】上記複合体では、炭化珪素結晶の平均粒径が２０μｍ以上という比較的大きな値に設定されているため、熱伝導率が従来と比べてより高くなっている。これは、熱が結晶の内部を伝導する効率は、熱が結晶間を伝導する効率に比べて一般的に高いため、平均粒径が大きいほど熱伝導率が高くなるからである。また、本発明の複合体では、焼結が進行し、図２の走査型電子顕微鏡写真（ＳＥＭ写真）に示したようにネック結合が大きくなっているため、さらに熱伝導率が高くなっている。しかし、図３のＳＥＭ写真に示したように、焼結が進行しない場合には、ネック結合も進行しないため、熱伝導率が高くならない。

【００１６】また、多孔質組織の気孔率が３０％以下という小さい値に設定されていることも、熱伝導性の向上に寄与している。すなわち、気孔率が小さくなると多孔質組織内における空隙が減少する結果、熱が伝導しやすくなるからである。さらに、炭化珪素１００重量部に対して１５～５０重量部の金属が含浸されていることも熱伝導率の向上に寄与している。

【００１７】上記複合体は、このように構成されている結果、熱伝導率の値が１００Ｗ／ｍ・Ｋ以上と大きな値となり、温度のバラツキも生じにくくなる。熱伝導率の値は、１８０～２８０Ｗ／ｍ・Ｋであることが好ましく、２００～２６０Ｗ／ｍ・Ｋであることがより好ましい。上記複合体では、上記開放気孔の気孔率や粒子の粒径等を、さらに好ましい範囲に設定することにより、上記した好ましい熱伝導率を達成することができる。

【００１８】上記複合体を構成する炭化珪素の平均粒径は、２０～１００μｍが好ましく、３０～９０μｍがより好ましく、４０～７０μｍが最も好ましい。平均粒径が大きくなりすぎると、複合体が過度に緻密化されてしまうおそれがある。また、上記炭化珪素の開放気孔の気孔率は、５～３０％が好ましく、１０～２０％がより好ましく、１０～２０％が最も好ましい。

【００１９】また、上記複合体は、平均粒径が０．１～１．０μｍの細かい炭化珪素結晶（以下、細結晶という）を１０～５０体積％含み、かつ、平均粒径が２５～１５０μｍの粗い炭化珪素結晶（以下、粗結晶という）を５０～９０体積％含むものであることが好ましい。

【００２０】上記のように、細結晶と粗結晶とが適宜の比率で含まれる複合体の場合、図４のＳＥＭ写真で示したように、粗結晶間に形成される空隙が細結晶で充填された状態となりやすく、実質的な空隙の比率が小さくなる。その結果、複合体の熱抵抗がいっそう小さくなり、このことが熱伝導率の向上に大きく貢献しているものと考えられる。一方、図５のＳＥＭ写真で示したように、粗結晶の回りに細結晶が存在しないと、ネック結合がある程度進行しても、空隙の比率が大きくなるため、熱伝導率が余り向上しない。

【００２１】細結晶の平均粒径は、０．１～１．０μｍが好ましく、０．２～０．９μｍがより好ましく、０．３～０．７μｍが最も好ましい。

【００２２】細結晶の平均粒径を極めて小さくしようとすると、高価な微粉末の使用が必要となるため、材料コストの高沸につながるおそれがある。逆に、細結晶の平均粒径が大きくなりすぎると、粗結晶間に形成された空隙を充填することができなくなり、複合体の熱抵抗を充分に低減することができなくなるおそれがある。

【００２３】この複合体において、細結晶は、１０～５０体積％含まれていることが好ましく、１５～４０体積％含まれていることがより好ましく、２０～４０体積％含まれていることが最も好ましい。細結晶の含有比率が小さくなりすぎると、粗結晶間に形成される空隙を充填するのに充分な量の細結晶が確保されにくくなり、複合体の熱抵抗を確実に低減することができなくなるおそれがある。逆に、細結晶の含有比率が大きくなりすぎると、上記空隙を充填する細結晶がむしろ過剰になり、本来、熱伝導性の向上に必要な程度の粗結晶が確保されなくなる。従って、却って複合体の熱抵抗が大きくなるおそれがある。

【００２４】上記複合体において、粗結晶の平均粒径は、２５～１５０μｍが好ましく、４０～１００μｍがより好ましく、６０～８０μｍが最も好ましい。粗結晶の平均粒径を小さくしようとすると、上記細結晶粒子との粒径差が小さくなる結果、細結晶と粗結晶との混合による熱抵抗低減効果を期待することができなくなるおそれがある。逆に、粗結晶の平均粒径が大きくなりすぎると、粗結晶間に形成される個々の空隙が大きくなることから、たとえ充分な量の細結晶があったとしても、当該空隙を充分に充填することが困難になる。よって、複合体の熱抵抗を充分に低減することができなくなるおそれがある。

【００２５】上記複合体において粗結晶は、５０～９０体積%含まれていることが好ましく、６０～８５体積%含まれていることがより好ましく、６０～８０体積%含まれていることが最も好ましい。粗結晶の含有比率が小さくなりすぎると、本来、熱伝導率の向上に必要な程度の粗結晶が確保されなくなり、却って複合体の熱抵抗が大きくなるおそれがある。逆に、粗結晶の含有比率が大きくなりすぎると、相対的に細結晶の含有比率が小さくなってしまい、粗結晶間に形成される空隙を充分に充填することができなくなる。よって、複合体の熱抵抗を確実に低減することができなくなるおそれがある。

【００２６】本発明の放熱板を構成する複合体では、炭化珪素１００重量部に対して１５～５０重量部の金属が含浸されている。金属含浸を行うことにより、金属が焼結体の開放気孔内に充填され、見かけ上は緻密体となり、結果として熱伝導性及び強度の向上が図られる。

【００２７】上記含浸用金属としては、特に金属シリコンが好ましい。金属シリコンは、炭化珪素との馴染みがよい物質であることに加え、それ自体が高い熱伝導性を有している。ゆえに、金属シリコンを焼結体の開放気孔内に充填することによって、熱伝導性及び強度の向上を確実に達成することができる。

【００２８】この場合、金属シリコンは、炭化珪素１００重量部に対して１５～４５重量部含浸されていることが好ましく、１５～３９重量部含浸されていることがより好ましい。含浸量が１５重量部未満であると、開放気孔を充分に充填することができなくなり、複合体の熱抵抗を確実に低減することができなくなるおそれがある。逆に、含浸量が３０重量部を超えると、結晶部分の比率が相対的に低下してしまう結果、場合によっては却って熱伝導率が低下してしまう可能性がある。

【００２９】なお、金属シリコン以外のもの、例えば、金属アルミニウムを選択した場合には、その含浸量は、炭化珪素１００重量部に対して２０～５０重量部が好ましい。含浸量が上記範囲を逸脱すると、熱伝導率の低下及び熱膨張率の増大を来すおそれがある。

【００３０】次に、このような複合体からなる放熱板を製造する方法について説明する。上記放熱板は、粗粉末に微粉末を所定割合で混合する材料調製工程、成形工程、焼成工程、及び、金属含浸工程を経て製造される。金属含浸工程は、焼成工程前に行われてもよく、焼成工程後に行われてもよい。

【００３１】上記材料調製工程においては、平均粒径５～１００μmのα型炭化珪素の粗粉末に対して、平均粒径０．１～１．０μmのα型炭化珪素の微粉末を１０～１００重量部配合し、これを均一に混合する。

【００３２】原料となるα型炭化珪素の粗粉末の平均粒径は、５～１００μmが好ましく、１５～７５μmがより好ましく、２５～６０μmがより好ましい。また、α型炭化珪素の微粉末の平均粒径は、０．１～１．０μmが好ましく、０．１～０．８μmがより好ましく、０．２～０．５μmが最も好ましい。

【００３３】粗粉末１００重量部に対する微粉末の配合量は、１０～１００重量部が好ましく、１５～６５重量部がより好ましく、２０～６０重量部が最も好ましい。

【００３４】この材料調製工程においては、上記炭化珪素粉末のほかに、ポリビニルアルコール、アクリル樹脂等の成形用バインダやアルコール、水、ベンゼン等の分散溶媒を必要に応じて配合し、これを振動ミル等により混合した後、ニーダー等を用いて混練することにより、原料スラリーを調製する。

【００３５】また、上記原料スラリー中には、さらに炭素源となる有機物が炭素重量換算で１～１０重量%配合されていることが好ましく、６～９重量%配合されていることがより好ましい。すなわち、上記有機物に由来する炭素が焼結体の炭化珪素の表面に付着することにより、侵入してきた金属シリコンと炭素とが反応し、そこで新たに炭化珪素が生成する。従って、そこに強いネッキングが起き、これにより熱伝導率及び強度の向上が図られるからである（図４参照）。

【００３６】上記有機物としては、例えば、フェノールレジン、カーボンブラック、アセチレンブラック、ピッチ、タール等が挙げられる。このなかでも、フェノールレジンは、ボールミルを用いた場合に、原料を均一に混合することができるという点で有利である。

【００３７】成形工程においては、この原料スラリーを用いて炭化珪素の顆粒を形成した後、金型等を用いて所定形状に成形する。炭化珪素粉末を顆粒化する方法としては、例えば、噴霧乾燥による顆粒化法（スプレードライ法）のように従来より公知の方法を用いることができる。また、成形圧力は、１．０～１．５ｔ／cm^2が好ましく、１．１～１．４ｔ／cm^2がより好ましい。また、得られる成形体の密度は、２．０ｇ／cm^3以上が好ましく、２．２～２．７ｇ／cm^3がより好ましい。

【００３８】焼成工程においては、得られた成形体を１７００～２４００℃の温度範囲で焼成して、多孔質体を作製する。焼成温度は、２０００～２４００℃が好ましく、２００～２３００℃がより好ましい。この際、焼成炉の内部は、アルゴン、ヘリウム、窒素等の非酸化性雰囲気又は不活性雰囲気に保つ。なお、このとき、焼成炉内を真空状態にしてもよい。

【００３９】さらに、焼成時においては、ネック部の成長を促進させるため、成形体からの炭化珪素の揮発を抑制することが好ましい。成形体からの炭化珪素の揮発を抑制する方法としては、外気の侵入を遮断可能な耐熱性の容器内に成形体を装入する方法がある。上記耐熱性の容器の形成材料としては、黒鉛又は炭化珪素が好適である。

【００４０】続く金属含浸工程においては、以下のようにして多孔質体に金属を含浸する。例えば、金属シリコ

ンを含浸する場合、前もって焼結体に炭素質物質を含浸することが好ましい。このような炭素質物質としては、例えば、フルフラール樹脂、フェノール樹脂、リグニンスルホン酸塩、ポリビニルアルコール、コーンスターチ、蜜糖、コールタールピッチ、アルギン酸塩等の各種有機物質が挙げられる。なお、カーボンブラック、アセチレンブラックのような熱分解物質も同様に使用することができる。

【００４１】上記炭素質物質を予め含浸させておくことにより、焼結体の開放気孔の表面に新たな炭化珪素の膜が形成されるため、これによって溶融シリコンと多孔質体との結合が強固なものになる。また、炭素質物質の含浸により、焼結体の強度も強くなる。

【００４２】金属シリコンを開放気孔中に充填する方法としては、例えば、金属シリコンを加熱溶融させて含浸する方法が挙げられる。また、微粉化した金属シリコンを分散媒中に分散させ、この分散液を多孔質体に含浸させた後乾燥させ、金属シリコンの溶融温度以上に加熱する方法も適用することができる。上記金属の含浸は、焼成を行う前の成形体に行われてもよい。この後、必要により焼結体に切削加工を施すとともに研磨等を施し、所定形状の板状体とすることにより放熱板を作製する。

【００４３】このようにして得られた新たな構成の炭化珪素・金属複合体からなる放熱板は、熱伝導率の値が１００Ｗ／ｍ・Ｋ以上と熱伝導性に優れるとともに、金属を含有しているため、機械的強度にも優れる。さらに、製造条件によっては、熱伝導率１８０～２８０Ｗ／ｍ・Ｋ、２００～２６０Ｗ／ｍ・Ｋとさらに熱伝導性に優れた放熱板とすることができる。このような放熱板は、下記するモジュール用基板等に使用する放熱板として最適である。

【００４４】次に、上記放熱板が用いられたモジュール用基板について説明する。本発明のモジュール用基板は、一主面に導体回路が形成された絶縁性基板と、上記絶縁性基板の他の主面に金属層を介して接合された放熱板とを備えた、半導体素子を搭載するためのモジュール用基板であって、上記放熱板には、上記した炭化珪素・金属複合体からなる放熱板が用いられていることを特徴とする。

【００４５】図1は、本発明のモジュール用基板が用いられたパワーモジュールを模式的に示す断面図である。

【００４６】このパワーモジュール１０では、絶縁性基板１２の上面に導体回路１５が形成され、この導体回路の一部に半導体素子１６が半田層１７を介して接続、固定されており、導体回路１５の他の部分と半導体素子１６とは、ワイヤー１５ａを用いたワイヤーボンディングにより接続されている。また、導体回路１５の一端には、外部端子１９が半田層１８を介して接続されている。

【００４７】一方、絶縁性基板１２の底面には、ほぼ全面に金属層１３が形成され、このアルミニウム等からなる金属層１３に、本発明の複合体からなる放熱板１１が直接接合され、この放熱板１１がクーリングユニット２０に取り付けられている。この放熱板１１は、アルミニウム等と熱膨張率が近い、Ａｌ－Ｓｉが添加されたロー材を介して金属層１４に接合されていてもよい。

【００４８】クーリングユニット２０は、空冷式であってもよく、水冷式であってもよい。水冷式の場合には、通常、放熱板１１と接する部分に水等の冷媒が流されている。

【００４９】このパワーモジュール１０では、導体回路１５と金属層１３とを有する絶縁性基板１２及び放熱板１１が、本発明のモジュール用基板を構成する。放熱板１１としては、上述した炭化珪素・金属複合体からなる放熱板を用いるが、この放熱板は、製造条件を選ぶことにより、例えば、２００～２６０Ｗ／ｍ・Ｋと極めて高い熱伝導率を示すとともに、機械的特性にも優れている。また、この放熱板１１は、室温～８００℃における熱膨張率が3.5×10^{-6}～5.0×10^{-6}（／℃）と窒化アルミニウム（熱膨張率：約4.5×10^{-6}／℃）等の絶縁性基板とほぼ等しいため、温度サイクルに対しても優れた耐久性を示す。なお、この放熱板１１の厚さは、通常、３～４ｍｍが好ましい。

【００５０】絶縁性基板１２の材質は特に限定されず、例えば、アルミナ、窒化珪素、窒化アルミニウム等が挙げられるが、これらのなかでは、熱伝導性に優れた窒化アルミニウムが好ましい。絶縁性基板１２が窒化アルミニウムからなる場合には、窒化アルミニウム焼結体は、アルカリ金属酸化物、アルカリ土類金属酸化物、希土類酸化物等の金属酸化物を０．１～１０重量％含有していてもよい。これらの酸化物としては、例えば、Y_2O_3、CaO、Li_2O、Rb_2O_3等が挙げられる。

【００５１】導体回路１５及び金属層１３の材質としては、例えば、銅、アルミニウム等が挙げられるが、比較的高い導電率を有するとともに変形抵抗の小さいアルミニウムが好ましい。特に、金属層１３にアルミニウムを用いた場合には、放熱板１１と直接接合することが可能となる。特に、放熱板１１に含浸させる金属としてアルミニウムやシリコンを用いると、このアルミニウムと放熱板中のアルミニウムやシリコンとが、接合界面で相互に溶融、混合されるため、両者は強固に接合される。なお、絶縁性基板と導体回路等の接合は、例えば、Ａｌ－Ｓｉを含むロー材を用いて行うことができる。

【００５２】本発明のモジュール用基板に搭載する半導体素子は特に限定されないが、該モジュール用基板は、放熱特性に優れているため、動作時に発熱量が多い半導体素子の搭載用として最適である。このような半導体素子としては、例えば、ＩＧＢＴ、ＳＩＴ等が挙げられる。このように本発明のモジュール用基板は、放熱特性に優れるとともに、温度サイクル等の熱衝撃に対しても

優れた耐久性を有している。

【００５３】

【実施例】以下に実施例を掲げて本発明を更に詳しく説明するが、本発明はこれら実施例のみに限定されるものではない。

【００５４】実施例１

まず、出発材料として、平均粒径３０μmのα型炭化珪素の粗粉末（＃４００）と、平均粒径０．３μmのα型炭化珪素の微粉末（ＧＭＦ－１５Ｈ２）とを準備した。そして、上記粗粉末１００重量部に対して、上記微粉末３０重量部を配合し、これを均一に混合した。

【００５５】次に、この混合物１００重量部に対し、ポリビニルアルコール５重量部、フェノールレジン３重量部、水５０重量部を配合した後、ボールミル中にて５時間混合することにより、均一な混合物を得た。

【００５６】この混合物を所定時間乾燥させて水分をある程度除去した後、その乾燥混合物を適量採取し、顆粒化した。このとき、顆粒の水分含有量を約０．８重量%になるように調整した。次いで、この混合物の顆粒を、金属製押し型を用いて１．３ｔ／ｃｍ^2 のプレス圧力で成形した。得られた板状の生成形体の密度は、２．６ｇ／ｃｍ^3 であった。

【００５７】次いで、上記成形体を黒鉛製ルツボに入れ、タンマン型焼成炉を使用してその焼成を行った。焼成は、１気圧のアルゴン雰囲気中において実施した。また、焼成時においては、１０℃／分の昇温速度で最高温度である２２００℃まで加熱し、その後は、その温度で４時間保持した。

【００５８】次いで、得られた多孔質焼結体にフェノール樹脂（炭化率：３０重量%）を予め真空含浸した後、乾燥を行った。その後、上記多孔質焼結体の表面に、金属シリコンを含むスラリーをコーティングした。ここでは、上記スラリーとして、平均粒径が２０μm、純度が９９重量%以上の金属シリコン粉末１００重量部と、５%アクリル酸エステル・ベンゼン溶液６０重量部とが混合されたものを用いた。そして、金属シリコンをコーティングした多孔質焼結体をアルゴンガス気流中で４５０℃／時間の昇温速度で加熱し、最高温度１４５０℃で約１時間保持した。このような処理により、金属シリコンを多孔質焼結体中に浸透させて、炭化珪素・金属複合体を得た。なお、ここでは、炭化珪素１００重量部に対する金属シリコンの含有量を３０重量部に設定した。

【００５９】得られた炭化珪素・金属複合体からなる基材は、多孔質組織における開放気孔の気孔率が２０%、全体として熱伝導率が２１０Ｗ／ｍ・Ｋ、全体としての密度が３．０ｇ／ｃｍ^3 であった。また、炭化珪素結晶の平均粒径は、３０μmであった。具体的には、平均粒径が１．０μmの細結晶を２０体積%含み、かつ、平均粒径が４０μmの粗結晶を８０体積%含んでいた。

【００６０】続いて、従来公知の手法により上記基材に面出し加工を施した後、研磨加工等を施し、縦：７０ｍｍ、横：１３０ｍｍ、厚さ：３ｍｍ放熱板の作製を完了した。

【００６１】次に、導体回路等を有する絶縁性基板として、一面に厚さ０．４ｍｍのアルミニウムからなる導体回路が、Ａｌ－Ｓｉを含有するロー材を用いて接合され、他の一面にアルミニウム板が同様のロー材を用いて接合された厚さ４ｍｍの窒化アルミニウム製基板を用い、得られた放熱板と上記窒化アルミニウム製基板とを、アルミニウム板を挟んで加熱、圧着することにより接合し、モジュール用基板の作製を完了した。

【００６２】得られたモジュール用基板を、－５５℃に保った後、１５０℃に保つヒートサイクルを１０００回繰り返すヒートサイクル試験に供した後、該モジュール用基板を縦に切断し、放熱板と絶縁性基板との接合状態や導体回路や金属層と絶縁性基板との接合状態を顕微鏡で観察したが、クラック等は全く観察されなかった。

【００６３】次に、このモジュール用基板に、ＩＧＢＴ素子を搭載し、クーリングユニットに取り付けた後、パワーモジュールを実際に作動させ、ＩＧＢＴ素子の温度を測定したが、ＩＧＢＴ素子は、素子として充分に機能し得る温度を保持していた。

【００６４】実施例２

平均粒径３５μmのα型炭化珪素の粗粉末（＃３６０）を用いるとともに、上記粗粉末１００重量部に対して、上記微粉末４０重量部を配合し、これを均一に混合した。それ以外の条件については、基本的に実施例１と同様とした。

【００６５】その結果、得られた炭化珪素・金属複合体からなる基材は、多孔質組織における開放気孔の気孔率が１７%、全体としての熱伝導率が２２０Ｗ／ｍ・Ｋ、全体としての密度が３．０ｇ／ｃｍ^3 であった。また、炭化珪素結晶の平均粒径は、３６μmであった。具体的には、平均粒径が１．０μmの細結晶を２０体積%含み、かつ、平均粒径が４５μmの粗結晶を８０体積%含んでいた。

【００６６】この炭化珪素・金属複合体を用い、実施例１と同様にモジュール用基板を作製しし、ヒートサイクル試験を行った後、放熱板と絶縁性基板との接合状態や導体回路の接合状態を観察したが、クラック等は全く観察されなかった。

【００６７】また、このモジュール用基板に、ＩＧＢＴ素子を搭載し、これをクーリングユニットに取り付けて作動させ、ＩＧＢＴ素子の温度を測定したが、ＩＧＢＴ素子は、素子として充分に機能し得る温度を保持していた。

【００６８】実施例３

平均粒径５７μmのα型炭化珪素の粗粉末（＃２４０）を用いるとともに、上記粗粉末１００重量部に対して、上記微粉末４０重量部を配合し、これを均一に混合し

た。それ以外の条件については、基本的に実施例１と同様とした。

【００６９】その結果、得られた炭化珪素・金属複合体からなる基材は、多孔質組織における開放気孔の気孔率が１５％、全体としての熱伝導率が２３０Ｗ／ｍ・Ｋ、全体としての密度が３．１ｇ／ｃｍ^3 であった。また、炭化珪素結晶の平均粒径は、６５μｍであった。具体的には、平均粒径が１．０μｍの細結晶を２０体積％含み、かつ、平均粒径が８０μｍの粗結晶を８０体積％含んでいた。

【００７０】この炭化珪素・金属複合体を用い、実施例１と同様にモジュール用基板を作製しし、ヒートサイクル試験を行った後、放熱板と絶縁性基板との接合状態や導体回路の接合状態を観察したが、クラック等は全く観察されなかった。

【００７１】また、このモジュール用基板に、ＩＧＢＴ素子を搭載し、これをクーリングユニットに取り付けて作動させ、ＩＧＢＴ素子の温度を測定したが、ＩＧＢＴ素子は、素子として充分に機能し得る温度を保持していた。

【００７２】比較例１

平均粒径１０μｍのα型炭化珪素の粗粉末を用いるとともに、上記粗粉末１００重量部に対して、平均粒径が０．７μｍのα型炭化珪素の微粉末４５重量部を配合し、これを均一に混合した。

【００７３】この混合物１００重量部に対し、ポリビニルアルコール５重量部、水５０重量部を配合した後、ボールミル中にて５時間混合することにより、均一な混合物を得た。

【００７４】この混合物を所定時間乾燥させて水分をある程度除去した後、その乾燥混合物を適量採取し、顆粒化した。次いで、この混合物の顆粒を、金属製押し型を用いて０．６ｔ／ｃｍ^2 のプレス圧力で成形した。得られた板状の生成形体の密度は、２．０ｇ／ｃｍ^3 であった。この後、この成形体に実施例１と同様の条件金属シリコンの含浸を行った。

【００７５】次いで、上記成形体を黒鉛製ルツボに入れ、タンマン型焼成炉を使用してその焼成を行った。焼成は、１気圧のアルゴン雰囲気中において実施した。また、焼成時においては、１０℃／分の昇温速度で最高温度である１７００℃まで加熱し、その後は、その温度で４時間保持した。

【００７６】得られた炭化珪素・金属複合体からなる基材は、多孔質組織における開放気孔の気孔率が３８％、全体として熱伝導率が８０Ｗ／ｍ・Ｋ、全体としての密度が２．８ｇ／ｃｍ^3 であった。また、炭化珪素結晶の平均粒径は、１０μｍであった。

【００７７】この炭化珪素・金属複合体を用い、実施例１と同様にモジュール用基板を作製しした。また、このモジュール用基板に、ＩＧＢＴ素子を搭載し、これをクーリングユニットに取り付けて作動させ、ＩＧＢＴ素子の温度を測定したが、ＩＧＢＴ素子は、時間の経過とともに温度が上昇し、素子として充分に機能し得る温度を超えてしまった。

【００７８】

【発明の効果】本発明の炭化珪素・金属複合体からなる放熱板は、上記のように構成されているので、熱伝導率が充分に高く、かつ、窒化アルミニウム基板との熱膨張率もほぼ等しいため温度サイクルに対する耐久性に優れ、発熱量の大きい半導体素子を搭載するためのモジュール用基板として好適に用いることができる。また、本発明のモジュール用基板は、上記のように構成されているので、放熱特性及び耐久性に優れる。

【図面の簡単な説明】

【図１】本発明のモジュール用基板を模式的に示す断面図である。

【図２】本発明の放熱板を構成する炭化珪素・金属複合体の組織を示すＳＥＭ写真である。

【図３】従来の炭化珪素・金属複合体の組織を示すＳＥＭ写真である。

【図４】本発明の放熱板を構成する炭化珪素・金属複合体の組織を示すＳＥＭ写真である。

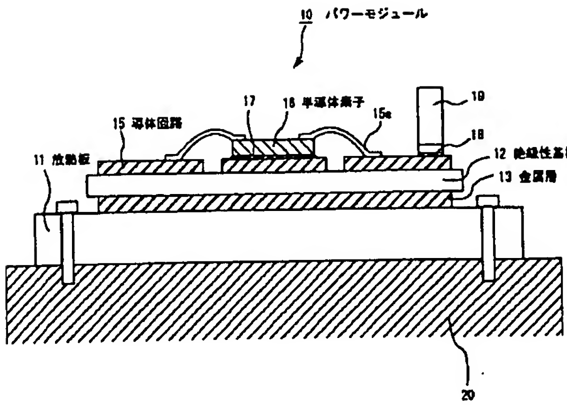
【図５】従来の炭化珪素・金属複合体の組織を示すＳＥＭ写真である。

【図６】従来のパワーモジュールを模式的に示す断面図である。

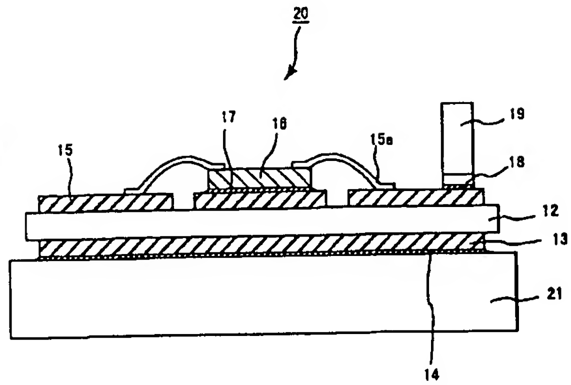
【符号の説明】

１０　パワーモジュール
１１　放熱板
１２　絶縁性基板
１３　金属板
１４、１７、１８　半田層
１５　導体回路
１５ａ　ワイヤー
１６　半導体素子
１７、１８　半田層
１９　外部端子

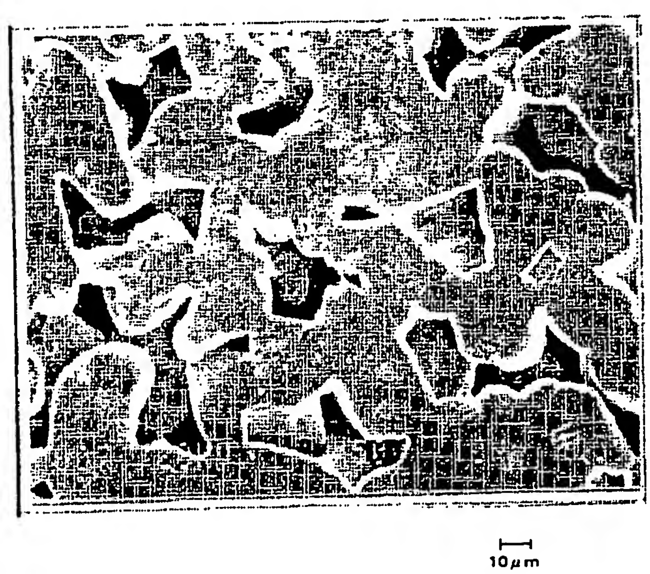
【図１】


10 パワーモジュール
17
16 半導体素子
15 導体回路
15a
19
18
11 放熱板
12 絶縁性基板
13 金属層
20

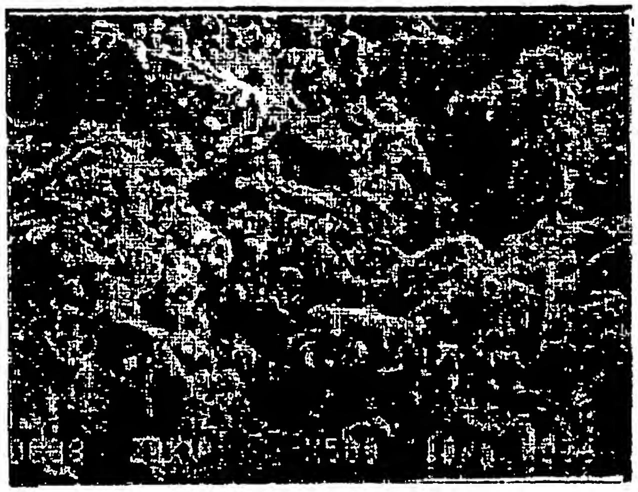
【図６】


20
17
16
15
15a
19
18
12
13
21
14

【図２】

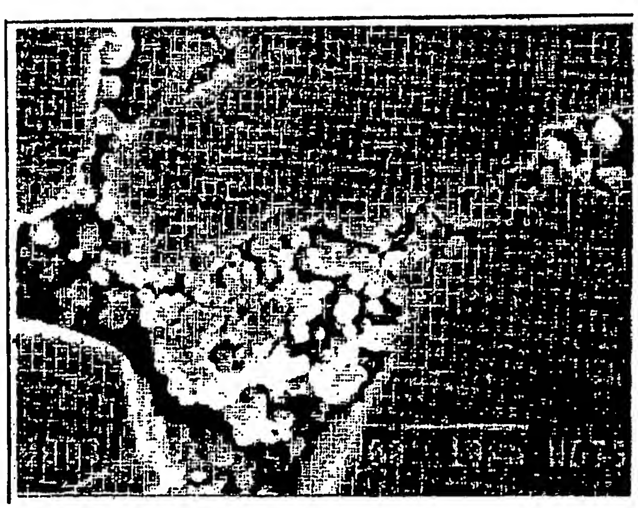

10μm

【図３】



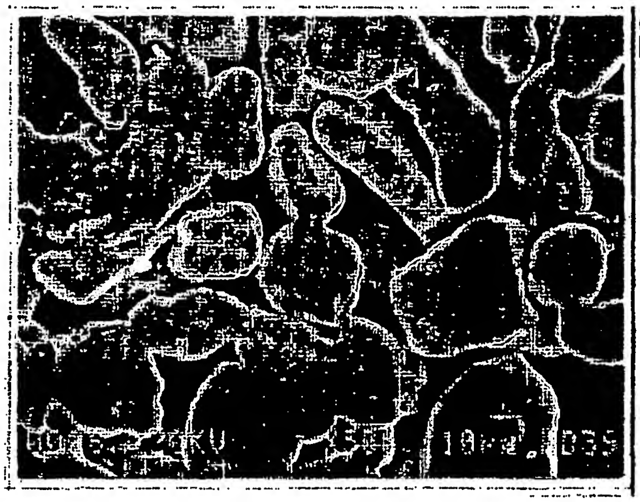
10μm

【図４】



10μm

【図５】



10μm